Report on a Study of Non-Military Defense

July 1, 1958

Report R-322-RC

THE RAND CORPORATION

Report on a Study of Non-Military Defense

July 1, 1958

Report R-322-RC

PREFACE

The study of non-military defense described in this report has been supported by The RAND Corporation as part of its program of RAND-sponsored research. In addition to its work for the United States Air Force and other government agencies, the Corporation regularly sponsors, with its own funds, research projects in areas of importance to national security and public welfare. RAND-sponsored research is considered to be fundamentally the responsibility of the individuals involved in the project, and the conclusions of such projects are not necessarily endorsed by the Corporation. Such studies are published in the hope that they may contribute to wider understanding of important national problems.

This study of non-military defense was initiated, directed, and formulated in its central features by Herman Kahn. Particular parts of the study were the responsibility of the following individuals, approximately in the order the subjects are mentioned in this report: Leon Gouré, foreign policy implications; Irwin Mann, improvised fallout shelters and other inexpensive measures; Robert Panero (from the staff of Guy B. Panero Engineers), mines and deep rock shelters; John O'Sullivan, conventional shelters and costs of complete shelter systems; Fred Iklé, strategic evacuation and social problems; Maj. Gen. Frank Ross, USA, ret., tactical evacuation; Leonard Berkovitz, performance of shelter systems under hypothetical attacks; Harold Mitchell, M.D., medical effects of radiation; Jerald Hill, long-term fallout problems; Joseph Carrier, food and agriculture; Paul Clark, economic recuperation after a 50-city attack; Norman Hanunian, heavier attacks and industrial shelters; Col. George Reinhardt, USA, ret., "starter set" and recuperation stockpiles; Harry Rowen, interactions with active offense; Philip Dadant, interactions with active defense; Richard Moorsteen, Soviet non-military defense capabilities. This summary report was drafted by Paul Clark.

A number of people in government agencies have been helpful in furnishing information and orientation. While it would be impossible to list them all, the assistance of the following should be acknowledged: Federal Civil Defense Administration—John Devaney, Gerald Gallagher, Jack Greene, Ralph Spears, Benjamin Taylor; Federal Reserve Board—Roland Robinson; Naval Radiological Defense Laboratory—Walmer Strope, Paul Tompkins; Office of Defense Mobilization—Joseph Coker, Brig. Gen. Harold Huglin, USAF, Burke Horton, Vincent Rock, Charles Sullivan; Science Advisory Committee—Spurgeon Keeney. Of course, none of the above are responsible for any portion of the study.

This report is unclassified, and no part of it depends on the use of classified information. In particular, the hypothetical attacks considered in evaluating various non-military defense measures should not be construed as statements of enemy offense capability or of U.S. defense capability. They are simply hypotheses about threats that appear conceivable sometime in the future and that provide a measure of the possible role of non-military defense systems. Moreover, this report has been written as a summary statement for general distribution; technical aspects of the study are not presented in full detail.

CONTENTS

REPORT ON A STUDY OF NON-MILITARY DEFENSE

I. Introduction: Initial Premises

This study was initiated in the belief that non-military defense measures, if they could be made effective in protecting the civilian population, economy, and institutions of the United States, might make two significant contributions to the national defense. First, they might alleviate the catastrophe of a nuclear attack and, if military victory were attained, provide a reasonable chance that the United States as a nation could survive. Second, they might increase U.S. freedom of action in conducting peacetime foreign policy and in implementing a broad deterrence strategy.

Alleviating the consequences of a nuclear war is an important objective in its own right. Even if a plausible attack a few years from now killed as many as 90 million Americans, it would still leave 90 million alive. However terrible the prospect, it would be worth investigating whether there are measures that might increase the number of survivors from 90 million to 120 or 150 million, and that might increase the likelihood that the survivors could, in time, restore the national economy and democratic institutions. The prospect is terrible enough to make the avoidance of general war—by deterrence or by any measures that might safely permit reduction in tension—the primary objective. However, general war may nonetheless occur, and it would be irresponsible to throw up our hands about the postwar world. (Note that this objective is quite distinct from that of defending a civilian basis for war production; a general nuclear war would almost surely be fought with military equipment on hand at the outset.)

Moreover, in the years ahead, willingness to make foreign-policy decisions carrying a risk of war may be important to meet major

Soviet challenges that threaten U.S. security. The more effective the defense of civilian society, the easier it will be for U.S. leaders to make such decisions. Deterrence of extremely provocative enemy behavior other than a direct attack on the United States might thus be maintained as a credible national policy. If non-military defense measures caused Soviet leaders to believe that aggressive moves would meet firm resistance, they would be less likely to take such provocative actions. Deterrence of aggressions against countries other than the United States might also be accomplished by strengthening U.S. capability to meet limited aggression in a limited way, and we believe it is important to do so. However, it is possible that some aggression may be difficult to deter or to meet except by a credible threat of all-out U.S. resistance. It is true that the likelihood of direct Soviet attack on the United States would be measurably increased, particularly in the case of an implicit or explicit U.S. threat. Furthermore, the level of destruction, if deterrence failed, would still be a subject for grave consideration by U.S. leaders. But these difficulties seem inherent in a foreign policy prepared to meet the range of possible Soviet threats.

It should be recognized that all-out nuclear war could start in many ways, other than by a premeditated Soviet attack. A local war might become so invested with national interests and prestige that Soviet leaders, if faced with decisive defeat, would choose to counter with an all-out attack. This danger has probably increased because Khrushchev seems less cautious than Stalin, less secure in his grasp of power, yet freer to exercise his diplomacy on a global scale. War might occur because of miscalculation of U.S. intentions; in a period of acute tension, verbal and even military indicators would be difficult to interpret, and the premium on a first strike might well tempt the USSR to launch a pre-emptive attack. War might even begin by accident, triggered by a chance release of weapons, and carried on because both sides were poised in a high state of alert for quick and nearly automatic retaliation. Finally, as just mentioned, we cannot rule out the possibility that the United States, faced with a major Soviet challenge, might sometime be forced to resist militarily, even at the risk of devastation.

It may also be noted that non-military defense measures could be more effective if war began in one of these other ways. A key factor in determining their effectiveness would be the ability of U.S. military forces to stop Soviet air attacks fairly quickly. Control of the military situation could be more quickly seized if the Soviet attack failed to achieve surprise, or if it were poorly executed, or if the United States were compelled to launch an attack. Non-military defense measures themselves would also work better with more warning, as will be more fully discussed later in this report. Such wars appear sufficiently probable to warrant careful investigation of the potentialities of non-military defense in these cases, as well as in the event of a premeditated Soviet attack.

The dependence of the defense of civilian society on the effectiveness of U.S. strategic-offense and active-defense capabilities should be stressed. Non-military defense measures must be evaluated not only with respect to feasibility, but also in their interaction with other aspects of national defense. They should not carry such high economic costs that U.S. strategic offense, air defense, or local-war forces would be dangerously weakened. Such an over-all evaluation of the place of non-military measures in the entire field of national defense has not been attempted in this study.

On the basis of such initial considerations, the premise on which this study was begun was that we should at least examine the feasibility of non-military defense measures in a nuclear war. Of course, after investigation we may conclude that defense of civilian society isn't practicable. The destructive power of a single nuclear weapon, the delivery capabilities of high-speed bombers and ballistic missiles, the seeming inability of any current or proposed air defense system to prevent the delivery by an intelligent attacker of at least a considerable number of nuclear weapons, the widespread vulnerability of cities, the slow reaction times of large civilian populations—all of these factors may well mean that effective non-military defense can't be obtained at an acceptable cost. But the issues seem so important that they should be seriously investigated.

This study is certainly not a definitive treatise on non-military defense. Rather, it was designed to provide an initial broad over-

view. It has seemed preferable to consider a large number of aspects of non-military defense, and to examine their interrelations, rather than to go more deeply into a few questions. The work has been done on a part-time basis by a number of people from different disciplines, and all the different pieces do not fit together perfectly. The pieces also differ in the research on which they are based: some involve quantitative calculations of the performance of possible non-military defense systems; others involve technical innovations and surveys of technical possibilities; still others are necessarily based primarily on reflection about nuclear war and national-defense strategy. Questions of the psychological reaction of the American people to a nuclear war and its aftermath remain largely unanswered. However, in the view of participants in the project, the study as a whole does provide a comprehensive orientation to non-military defense problems that is fundamentally sound.

II. Population Shelters

The first big question that must be raised about non-military defense is whether people can in fact be protected from modern nuclear weapons. Protection involves not only provision of shelters capable of withstanding blast and fallout effects, but also arrangements for getting people into the shelters in response to different kinds of warnings. It should be stated at the beginning that it is impossible to provide reliable protection for all the population, and that the fraction of the population effectively protected depends greatly on the essentially uncertain nature of the enemy attack. There appear to be a number of possibilities for protective systems, however, and under plausible assumptions about the enemy attack and the civilian response, significant—and in some cases dramatic—reductions in civilian casualties appear to be obtainable.

TYPES OF SHELTERS

Improvised fallout shelters, even if only capable of reducing radiation to $1/20$ or $1/30$ of the radiation outside, could have a significant effect in reducing casualties among people outside the areas of blast damage. There seem to be many possibilities of identifying and preparing such shelters in existing buildings in small cities and towns. For example, a location in the center of the basement of a 40,000-square-foot building (a typical large office, store, or school building) may provide an attenuation to about $1/80$. Moreover, a foot of earth gives a reduction to about $1/30$, and sandbags distributed in advance could be quickly filled and placed to provide this type of shielding. Even buildings whose structural characteristics provide smaller attenuation factors could be quite useful, with arrangements for washing down or sweeping the roofs and surrounding areas (exposure to carry out the decontamination being rationed among the shelter inhabitants).

An essential element in the use of such improvised fallout shelters would be radiation meters. The meters would indicate how long outside activity could continue (until heavy fallout arrived), would guide immediate decontamination work, would show when it was safe to emerge from the shelters, and would continue to be needed in postwar reorganization. Two main types of meters are available: a dosimeter, which measures cumulative radiation exposure over an interval of time and which might cost $1 to $5, depending on the model, and a dose-rate meter, which would be more convenient in some operations but might cost $15 to $20. Predistributing one dosimeter for every five persons in the country and one dose-rate meter for every fifty might thus cost $150 million to $250 million spread over several years.

An often-neglected possibility is the use of suitably located mines for both fallout and blast protection. Mines for low-priced ores, such as limestone, sandstone, rock salt, and gypsum, typically consist of a regular pattern of rooms with level floors and 10- to 12-foot ceilings, completely self-supporting and dry. An engineering calculation prepared as part of the study indicated that a limestone mine at West Winfield, Pennsylvania, could be prepared for emergency 7-day occupancy at a cost of $25 to $35 per person (or more strictly, per shelter space). Such a mine would be provided with water tanks, latrines, utilities, and some air-conditioning equipment, and would be stocked with a bedroll for each person, cold processed rations, and some medical supplies.

A wide range of shelter designs providing blast protection of 50 to 200 psi (pounds per square inch above normal atmospheric pressure) seems to be possible using conventional construction techniques —shallow underground location, reinforced concrete or corrugated-steel material, and heavy air-tight blast doors.

There are still technical engineering uncertainties about many aspects of these designs, but corrugated-steel shelters buried fairly deep look promising and are much cheaper than shelters of reinforced concrete. There is also uncertainty about the number of square feet to be provided per person, ranging from the 5 square feet in European shelters for short-time occupancy, to the 20 square feet in

the Manhattan design discussed below. However, a reasonable guess is that bunkroom-type accommodations for 90-day occupancy could be provided for something on the order of $300 to $400 per person. Such "medium" shelters might be appropriate for suburban fringes of large cities and for small cities that are presumed to be lower-priority enemy targets.

"Light" shelters, primarily for fallout protection, would of course be cheaper—perhaps $150 per person. Constructed shelters should be designed to provide much greater attenuation of surrounding radiation than improvised shelters; fortunately, 3 feet of earth provides attenuation to about $\frac{1}{1000}$ of the radiation outside. Moreover, most fallout shelters ought to be planned and placed deep enough so that they could later be made into blast shelters in the 20- to 100-psi range, primarily by adding better blast doors. With appropriate evacuation procedures, such "light" shelters in towns and rural areas might be used by more people than any other type.

Finally, deep rock shelters created by mining rather than by construction techniques appear to be the most promising approach (where sound rock is available) for blast protection in the range of 500 psi to several thousand psi. Such "heavy" shelters would be indicated if a serious attempt were made to provide protection, other than by evacuation, for residents of large cities. Shelters with lower levels of protection might become partially obsolete soon after they were built. An engineering calculation of a system of deep rock shelters under Manhattan Island for 4 million people indicated a cost of $500 to $700 per person, depending largely on habitability standards. The shelters were to be excavated 800 feet below the surface, using conventional excavation and mining techniques. They were to be almost completely isolated from the surface, with air purified and enriched with oxygen as in a submarine, with water tapped from the Delaware Aqueduct system of tunnels and treated (or, in emergency, drawn from internal storage), and with power provided from diesel generators vented to the surface but isolated from the shelters proper. Occupants would be assigned berths in a large dormitory, would receive two cold meals and one hot meal per day, and would draw fresh clothing, take showers, and exercise on a

rotational basis. Some 91 entrances were planned and distributed according to population, so that every point in Manhattan was within 5 to 10 minutes' walking distance of an entrance; elevator design characteristics currently employed in New York should permit about a fourth of the people in the buildings themselves to reach the street every 5 minutes. The entrances were sloped tunnels and had 500-psi blast doors both at the top and at the bottom; provision could be made to collapse any single tunnel if the upper door gave way.

The point of this quick survey of types of shelters is that the possibilities seem to be both more varied and more promising than has been generally realized. However, while several kinds of shelters could be built today, one of the conclusions of this study is that a great deal of research and development work should be done before any attempt is made to decide on final shelter designs. Further preparation could both improve performance and lower cost.

WARNING AND MOVEMENT

If people are to get into shelters, an appropriate movement plan and some warning are needed. It is convenient to distinguish three degrees of warning—measured in days, in hours, or in minutes. Correspondingly, three general kinds of movement are possible: strategic evacuation, tactical evacuation, and ducking into the nearest shelter entry.

Warning measured in terms of days is possible if a nuclear attack occurs as an extension of a local war, or after a period of severe international tension, or as a last-resort decision by the United States. In each case the warning does not consist in discovery of secret enemy intentions to attack, but in recognition that an attack has become more likely and that the vulnerability of the civilian population should be reduced. Strategic evacuation—that is, movement of a significant fraction of the city population into emergency quarters in small towns and rural areas—would then be possible. Indeed, some evacuation would doubtless occur spontaneously. The prime historical example is the evacuation of children and mothers from London and other English cities in 1939, which reduced London's

population by 25 to 35 per cent by the time war was declared.

Warning measured in hours is crucially dependent on the tactics chosen by the enemy. However, one sensible enemy plan would be to concentrate his first wave, largely ICBM's plus some submarines and long-range bombers, upon the retaliatory capacity of the Strategic Air Command, and to defer a general city attack for a following wave, largely of medium bombers refueled en route. Cities spared on the first attack wave might possibly have several hours of warning. Initial investigation suggests that in most cities, particularly the medium and small cities most likely to survive the first wave, an organized tactical evacuation could be carried out within 3 to 6 hours. The objective would be to move the bulk of the city population out to a shelter belt extending 20 to 50 miles from the center; less warning or slower movement would simply reduce the fraction of the people saved. The key organizational principles for such a movement appear to be one-way routes, maximum loading of vehicles (with emphasis on trucks and buses), prior instruction to each vehicle owner (perhaps on his registration certificate), and some limited test movements. Provision of shelters in the peripheral belt —ranging from "medium" blast shelters to improvised fallout shelters according to location—would be important, however; otherwise many evacuees might flee the city only to succumb to fallout.

Warning measured in terms of minutes is likely to be all that would be available for cities that the enemy chose to attack in his first wave, or possibly with a following salvo of ICBM's. Even in this case it appears to be technically feasible, as suggested in the Manhattan calculation, to design "heavy" shelters into which the bulk of the population could conceivably duck in 30 to 60 minutes— or a smaller fraction of the population if less time were available. A dramatic and unequivocal signal, such as exploding a small atomic weapon at a very high altitude over the city, would help in getting people to move quickly. But given the slow reaction time of the civilian population, it seems inevitable that non-military defense measures in cities with only minutes of warning would be much less effective than elsewhere.

It should also be stressed at this point that the tactics chosen by

an attacker, and hence the amounts of warning available to various cities, are very much a function of the posture of the Strategic Air Command and the effectiveness of U.S. air defenses. Unless SAC is so sheltered and defended that an enemy would have to concentrate nearly all of his first strike on attempting to destroy SAC's capacity to retaliate, warning sufficient for tactical evacuation—or even for ducking into "heavy" shelters—might not be available for many cities. The interaction of non-military defense with active offense and active defense is further discussed in Section VI, below.

Finally, it may be noted that in nontarget areas there would be 1 to 10 hours of delay between the explosion of bombs on targets and the arrival of airborne fallout. This delay would give time for entering designated fallout shelters, strengthening them with sandbags or window closures, filling water tanks and packing in home stocks of foods, and billeting evacuees from the cities.

PERFORMANCE OF POSSIBLE SHELTER SYSTEMS UNDER HYPOTHETICAL ATTACKS

A rough measure of the possible effectiveness of certain shelter systems is provided by some calculations of population casualties made as part of the non-military defense study. Two possible shelter systems were considered: a system of fallout shelters only (largely improvised in the next few years, supplemented with shelters of light construction by the mid-sixties), and a system of heavy, medium, and light shelters designed to provide both blast and fallout protection for the entire population (and available no earlier than the mid-sixties). The effect of prior strategic evacuation of 70 per cent of the population in the large cities attacked was also examined for each system.

Two hypothetical levels of enemy attack were considered, with variants to take into account the amounts of warning received by large cities. The first level was defined as the ***delivery on target*** of sufficient weapons to destroy all buildings in the 50 largest urbanized areas (many receiving several weapons) plus all the SAC bases. The list extended to cities the size of New Haven, Connecticut, with a

population of about 250,000. (It should be stressed that this hypothetical attack was not based on an analysis of enemy capability in the light of U.S. defenses, but was adopted as a means of measuring the performance of possible shelter systems. Approximately the same level of attack was also considered in other parts of the over-all study.) Calculated fatal casualties in the various cases hypothesized are summarized in Table 1, below.

Table 1

CALCULATED PERFORMANCE OF ALTERNATIVE SHELTER SYSTEMS UNDER VARIOUS ATTACKS

(Millions of U.S. fatalities out of 180 million population)[a]

50-CITY ATTACK

Non-Military Defense System	30 to 60 Minutes of Warning	3 to 6 Hours of Warning
No non-military defense measures	90	90
System of fallout shelters plus arrangements for tactical evacuation	70	30
Same, after strategic evacuation	25	5

150-CITY ATTACK

Non-Military Defense System	30 to 60 Minutes of Warning[b]	3 to 6 Hours of Warning[b]
No non-military defense measures	160	160
System of fallout shelters plus arrangements for tactical evacuation	85	60
Same, after strategic evacuation	40	25
System of blast and fallout shelters plus arrangements for rapid entry	25	25
Same, after strategic evacuation	5	5

[a] For comparability the same population was assumed for both attacks, even though the 150-city attack was presumed to occur further in the future.

[b] Includes 10 cities hit by ICBM's with no warning.

With no non-military defense measures, a completely effective 50-city attack might be expected to cause 90 million deaths in the United States, that is, half of a projected population of 180 million. With a system of fallout shelters, but with an enemy tactic of hitting the cities on the first wave or soon thereafter, about 70 million

deaths might result. With the same fallout protection, plus several hours' warning for the cities so that a substantial tactical evacuation could be carried out, the casualty figure might be reduced to 30 million. Finally, if the attack occurred after strategic evacuation, casualties might be held down to 5 million to 25 million people, depending on the amount of warning to the large cities.

The second level of attack was defined as the delivery on target of sufficient weapons to destroy all buildings in about 150 urbanized areas and all the SAC bases, and also to generate widespread lethal fallout. The list extended to cities such as Asheville, North Carolina, with a population of about 60,000. This hypothetical attack was presumed to occur at a later time. Accordingly, it was assumed that 10 of the 20 largest cities would be hit by ICBM's in the first wave, and that following ICBM's would make tactical evacuation in some of the other cities less effective than in the earlier calculation. On the other hand, the later time-period also made a more complete blast-and-fallout shelter system at least conceivable.

With no non-military defense measures, a completely effective 150-city attack could result in 160 million deaths in the United States —that is, almost 90 per cent of the total population could be killed. With a system of fallout shelters, and given several hours' warning to carry out a partly disrupted tactical evacuation in all cities except those hit on the first wave, casualties might be reduced to 60 million. With a complete system of blast-and-fallout shelters, and even with only 30 to 60 minutes of warning, casualties might be held to 25 million. Less warning would, of course, increase the casualties if only a system of fallout shelters were provided, while prior strategic evacuation would result in still fewer casualties with either system.

A further word should be said about these hypothetical attacks. Even if an enemy had the initial capability to completely destroy 50 or 150 large cities, it is not certain that he would do so in actual war. Successful accomplishment of a large retaliatory strike by SAC, and effective operation of U.S. air defenses, might so reduce the enemy's forces that he would not be able to take out so many cities. Or the war might start in one of the less premeditated ways mentioned earlier, so that the enemy's strikes would be small and uncoordinated.

Or he might not attempt such widespread destruction, because the military payoff from destroying cities is low, and because he might hope to use the threat of further destruction to reinforce a surrender demand.

On the other hand, even with the assumed shelter systems, heavier casualties and more extensive destruction are also conceivable. Unless U.S. active offenses and active defenses can gain control of the military situation after only a few exchanges, an enemy could, by repeated strikes, reach almost any level of death and destruction he wished. Even on a first strike, if an enemy—perhaps motivated by memories of World War II—allocated a larger part of his force to the destruction of cities rather than to an attempt to prevent retaliation by SAC, he could increase casualties by reducing warning and hitting more cities.

These casualty calculations are far from definitive. In addition to the intrinsic uncertainty concerning the size of the enemy's attack and his tactics, the model used was simple and subject to error. But the major implications of the calculations are probably valid. A system of fallout shelters might save tens of millions of lives in either a 50-city or a 150-city attack. A complete system of blast-and-fallout shelters would, of course, be more effective; and in the case of a 150-city attack, such a system would probably be needed to hold fatalities below a third of the population. Both systems would be affected by the amount of warning available, and sufficient time for tactical evacuation would be particularly important for effective use of the fallout shelters. Prior strategic evacuation, if this were possible, could make a large improvement in the performance of either system. Thus the effectiveness of non-military defense systems would vary greatly with circumstances, but the cases in which performance is promising seem sufficiently likely to warrant serious consideration.

III. Long-term Fallout

The second major question that must be examined in connection with non-military defense is whether the population can survive the long-term radiation levels resulting from fallout. There would be little point in sheltering people from the instantaneous blast and short-run fallout effects of a nuclear attack if they emerged from the shelters into an atmosphere so radioactive that life could not be sustained. Long-term radiation appears particularly threatening in the light of current widespread fears about the consequences of nuclear testing—which releases only a fraction of the radioactive materials that would be released in an all-out nuclear war.

The criterion that we shall use here in examining the consequences of long-term fallout, however, is quite different from the criterion generally used in discussing nuclear tests. There the concern is commonly with keeping radiation levels low enough so that the number of people who might be injured is small in a "statistical" sense; here the concern is with evaluating the extent of further biological damage, relative to the number of people who survive the immediate catastrophe of nuclear war. We are also interested in any measures that might reduce the long-term biological damage, even though considerable damage seems inevitable.

MEDICAL CONSEQUENCES OF RADIATION

Medical evidence on the ability of the human body to sustain instantaneous or short-term exposure to total body radiation is reasonably clear; something like 200 roentgens will cause serious illness and some deaths. Evidence about heavier doses is more ambiguous, but about 450 roentgens seem likely to cause a 50 per cent death rate; and perhaps 600 roentgens will cause virtually 100 per cent fatalities. Holding the short-term exposure below 200 roentgens for a large part of the population is one of the essential functions of a system of population shelters.

The consequences of chronic lifetime exposure to radiation are not so clear. There is evidence, however, that long-term damage can be assessed largely in terms of decreased life-span; increases in such specific diseases as leukemia are statistically less important than increases in death rates from all causes. Moreover, analysis and extrapolation of data on radiation damage to animals suggest that a reasonable though uncertain estimate of the extent of life shortening might be something like 7 years per 1000 roentgens for children, and less for adults. (Observations on the life-span of radiologists in comparison to other physicians less exposed to radiation indicate that the animal data are not optimistic.) General life shortening of this sort would be a real human tragedy, but would hardly threaten survival of the population; it may be noted that about 10 years have been added to the adult life-span in the United States since 1900 (apart from reductions in infant mortality, which have added an additional 10 years to over-all life expectancy).

Genetic effects of long-term radiation are even more difficult to estimate reliably, because the observed cases in existing studies of survivors of Hiroshima and Nagasaki and of American radiologists are so few as to barely meet accepted standards of statistical significance. However, the following statements appear to be reasonable—though again uncertain. For each 50-roentgen exposure of one parent, there may be an increase of one in a thousand in the number of harmfully affected offspring as a result of dominant mutations. Recessive mutations would only rarely produce serious malformation in immediate offspring, and their effects in lowered fertility and vigor would be spread out over many subsequent generations. Again the total human cost over time would be great, but the medical problem in any one generation could be handled. At present about 4 per cent of babies are stillborn or die shortly after birth, 2 per cent are malformed, and 2 per cent develop troubles later that are based on hereditary defects. Thus 1000 roentgens of long-term radiation to both parents might increase the chance of producing a seriously defective child from 8 per cent to perhaps 12 per cent.

The medical consequences of internal deposition of strontium-90, cesium-137, and other radiation products taken into the body with

food and water must also be considered. Strontium-90, which is chemically similar to calcium, is incorporated in the bone structure, and in sufficiently high concentrations causes bone cancer, and possibly leukemia. Extrapolating from cases of radium-caused cancer, it appears that a concentration of strontium-90 between 10 and 100 microcuries is the range from a statistically significant rise in bone cancer to serious difficulty with large numbers of cancer cases. This range, while uncertain, is used in the fallout calculations in the next section; here it may be noted that at present in the United States new bone is being laid down with a concentration of about 0.001 microcuries. The medical danger from cesium-137 appears to be less serious. In the untreated situation, cesium-137 and strontium-90 would probably enter the body at about the same rate. However, physical and biological factors combine to allow us to accept a ratio of 90 to 1 in calculating maximum permissible concentrations of cesium-137 relative to strontium-90. The medical danger from other isotopes deposited after a nuclear explosion needs further investigation, but present evidence indicates that strontium-90 and cesium-137 pose the most serious problems.

LONG-TERM FALLOUT LEVELS AFTER HYPOTHETICAL ATTACKS

The seriousness of the long-term radiation problem has been examined with the aid of two fallout calculations, based again on two hypothetical enemy attacks. The first attack, which corresponds approximately to the 50-city attack discussed previously, was defined as an attack that releases about 1500 megatons of fission products. The second attack was based on the extreme hypothesis of 20,000 megatons of fission products. (Note that this attack is much heavier than the 150-city attack discussed above; we shall call it an area attack, because with certain enemy tactics its blast effects might be sufficient to destroy all structures in entire states or regions.) This area attack was assumed in order to examine long-term fallout problems far more serious than have generally been considered.

Before examining the results of the fallout calculations, let us note three characteristics of fallout that are important in interpreting the calculations. First, fallout would be quite unevenly distributed over the United States, particularly after a 50-city attack. This raises the possibility of people living and raising food primarily in the less-contaminated areas of the country. To point up this unevenness, the calculations specify average fallout levels (the total deposit divided by the U.S. area), maximum fallout levels (applying to only a small fraction of the country and based on a geographical analysis of assumed targets, with allowance for overlap of fallout patterns), and minimum fallout levels (based on the U.S. share of worldwide fallout resulting from equal attacks on the United States and the USSR).

Second, fission products decay with the passage of time. The rate of decay is conventionally approximated with a formula involving the factor $t^{-1.2}$, which implies that the radiation rate a week after an attack would be 0.2 per cent of the 1-hour rate, and after 90 days would be 0.01 per cent. The actual dose levels would be ½ to ⅕ of those computed with the formula, because of large- and small-scale roughness of terrain, weathering, and deviations from the $t^{-1.2}$ decay rule. The calculations below are all standardized to refer to the period starting 90 days after the attack. It is, of course, recognized that fallout protection immediately after the attack must first be adequate to hold total radiation below 200 roentgens for the bulk of the population.

Third, countermeasures are possible to reduce the radiation that people receive. Decontamination, by washing or sweeping hard surfaces, and by plowing or scraping earth areas, can reduce residual radiation to levels ⅕ to 1/100 of those prevailing previously. Shielding buildings with earth or concrete can produce almost any attenuation desired; shielding to 1/10 or 1/100 of radiation levels outside is possible even on mobile equipment such as bulldozers. Once a few protected areas are available, radiation damage can be limited by rationing the number of hours per day that individuals have to work in a contaminated environment. In the calculations below, it is assumed that all dose rates would be reduced to 1/100 of the level computed with

the $t^{-1.2}$ formula—perhaps 1/10 for decontamination, multiplied by 1/5 for shielding and time-rationing, multiplied by ½ for more rapid decay than in the $t^{-1.2}$ formula.

Countermeasures to reduce people's consumption of strontium-90 in food and water are also available. Among such measures are those of shifting part of agriculture to less contaminated land; decontaminating cropland by deep plowing or scraping; maximum use of crops such as potatoes and wheat, which have low concentrations of strontium-90 in their edible portions; reducing normal consumption of calcium and replacing it with calcium pills from uncontaminated mineral sources; and, where necessary, removing fission products from drinking water by filtration or precipitation. Other possible countermeasures may be developed by research, including chemical treatment of soils to leach out strontium-90 or to limit its absorption by crops, development of food-processing methods that would reduce the content of fission products, and discovery of medicines that would limit retention of strontium-90 by people and animals. No quantitative allowance for these specific countermeasures against strontium-90 has been made in the calculations below.

The fallout calculations are summarized in Table 2 on page 20. In the case of a 50-city attack, the cumulative lifetime exposure to external total body radiation (after 90 days, with countermeasures), averaged over the area of the United States, might be less than 5 roentgens. The maximum in some areas might be about 75 roentgens, but a map study indicates that more than 85 per cent of U.S. land area would receive less than the average contamination. Thus if short-term radiation could be held below 200 roentgens for the bulk of the population, the additional long-term problem would be comparatively small. The general shortening of lives and genetic consequences resulting from short-term and long-term radiation combined would apparently be below the range discussed in the previous section.

As to strontium-90, the estimated long-term accumulation resulting from a 50-city attack, averaged over the entire United States, is 2 microcuries. (Note that the average is more representative for strontium-90 than for total radiation, because strontium-90 enters the

Table 2

ESTIMATED LONG-TERM RADIATION AFTER VARIOUS ATTACKS

1500 MEGATONS OF FISSION PRODUCTS (50-CITY ATTACK)

	Average	Maximum	Minimum
Total fallout (kilotons per square mile)	0.4	8.3	0.003
Radiation rate after 90 days with countermeasures[a] (milliroentgens per hour)	0.46	10	0.0035
Cumulative lifetime exposure[a] (roentgens)	3.4	73	0.026
Strontium-90 fallout (curies per square mile)	40	830	0.3
Cumulative lifetime concentration in bone without countermeasures (microcuries)	2	42	0.015

20,000 MEGATONS OF FISSION PRODUCTS (AREA ATTACK)

	Average	Maximum	Minimum
Total fallout (kilotons per square mile)	5.3	36	0.04
Radiation rate after 90 days with countermeasures[a] (milliroentgens per hour)	6.5	43	0.049
Cumulative lifetime exposure[a] (roentgens)	48	310	0.36
Strontium-90 fallout (curies per square mile)	530	3600	4
Cumulative lifetime concentration in bone without countermeasures (microcuries)	26	180	0.2

[a] Assumes that radiation rates are reduced to 1/100 of the level computed with the $t^{-1.2}$ formula, because of decontamination, shielding and time-rationing, and inaccuracy in the formula.

body in food presumably grown in all parts of the country. However, the relation between total fallout and ultimate physiological exposure is also more uncertain for strontium-90.) This is below the range discussed in the previous section, so it seems likely that strontium-90 would not create a critical public health problem, even without countermeasures.

In the case of the extremely heavy hypothetical area attack, the cumulative exposure to total radiation, averaged over the entire United States, might be about 50 roentgens. The maximum figure might be about 300 roentgens, however, and possibly less than half of the U.S. land area would have less than the average contamination. Thus more extensive radiation-control measures over a longer period of time would be indicated. But even in this case the medical and genetic effects of the combined short-term and long-term radiation would apparently be below the range examined earlier.

As to strontium-90, the long-term accumulation after an area attack has been estimated at about 26 microcuries, on the average, for the United States. This *is* within the range from statistically significant rise in bone cancer to generation of widespread cancer in the population. In this case, therefore, extensive and continuing countermeasures against strontium-90 would almost surely be needed. Fortunately, accumulation of strontium-90 in the body is a lifetime process, so there would be time to make such countermeasures effective.

To conclude: Despite many unresolved questions about long-term fallout, it seems to be a sound generalization that long-term radiation problems are a less critical threat to the survival of a population than the central short-term problem, namely, how to protect a substantial fraction of the population from the immediate disaster of a nuclear war.

IV. Recuperation of the Economy

The third basic question that must be weighed in considering non-military defense is whether a viable economy could be reconstructed after a nuclear war. If a large fraction of the population could be sheltered from the immediate attack, and if they could survive the long-term radiation that followed, could they also go on to support themselves and to restore a "reasonable" standard of living in less than a generation? We are, of course, also interested in noting any promising preattack or postattack policies that might facilitate economic recuperation.

REORGANIZATION PROBLEMS

The initial phase of economic activity following a nuclear attack would be dominated by reorganization problems, so that any resources that survived the attack could again be effectively used. These reorganization problems have been a major concern of existing government agencies in the non-military defense field, and little further effort was devoted to them in this study. Some of the problems are physical, such as the patching up of capital that has suffered only partial damage (for example, electric-power grids, open-hearth furnaces without chimneys), decontamination of factories immobilized by fallout, and even the disposal of millions of dead. Other pressing problems are institutional: preservation of the governmental framework, restoration of a monetary system and of decision-making authority in business enterprises, re-establishment of markets for consumer goods and raw materials (though doubtless controlled in certain respects), and activation of the labor force so that people support themselves by regular work (often in new occupations). In all of these instances, prior planning, based on a realistic appraisal of the postattack situation, seems to be the essential approach. For example, prior stocking of radiation meters and manuals, and

possibly even detailed plans, would be critically important for decontamination.

Given reasonable preattack preparations, these reorganization problems do not appear insuperable. In particular, we should not underestimate the strength in an emergency of a decentralized private-enterprise economy and of widespread ingenuity among the people. Accordingly, in the following analysis it has been assumed that extensive reorganization could be accomplished within perhaps 6 months, so that any economic resources that survived could be effectively used thereafter.

FOOD

During the reorganization phase, the bulk of the food and other consumer goods needed to sustain life would have to come from inventories or from imports rather than from domestic production. A thorough investigation of the normal geographical location of such inventories, and of the relation of probable surviving inventories to truly minimal needs of the population, is a bigger research job than could be done in this study. However, a rough estimate indicates that surviving food inventories, after either a 50-city or a 150-city attack, would be sufficient at least for survival. The government now has a large store of agricultural products accumulated in price-support operations; stocks of wheat, corn, and other grains on September 30, 1957, were sufficient to supply 2000 calories per day to 180 million people for more than 1 year. These government stocks are dispersed so as to be largely invulnerable to a city attack, they (as well as crops close to harvesting) are not made unfit for human consumption by fallout, and after some milling any grain is suitable for human consumption as an emergency diet. There are substantial further stocks in private hands. Emergency grain imports from Australia, Argentina, and other producing countries are also an important possibility.

The cost of 3 months' shelter rations for the entire population has been looked into to some extent. Minimum nutritional needs could probably be met by a source of calories (wheat flour and sugar

being cheapest), a source of protein (such as soy grits), and supplementary minerals and synthetic vitamins. The cost of 2000 calories of this minimum diet at wholesale prices would be something like 15 cents per person per day. Allowing for a somewhat more palatable food-mix and for packaging, a conceivable total cost figure might be 40 cents per person per day. Thus 3 months' rations for 180 million people might be expected to cost $6 billion to $7 billion initially, plus some recurring storage and deterioration costs. Such a stockpile of rations would be an essential element of a complete system of blast-and-fallout shelters in which the population might live for several months, and is an important subject for further research.

Turning to the production of food after the reorganization phase, it is reasonably clear that a 50-city attack would not be a serious threat to the recuperation of U.S. agriculture. At present, 320 million to 340 million acres of cropland are harvested annually. But only about 20 per cent are used to produce food for human consumption, the balance being used to produce industrial crops and feed for livestock. Further, the Department of Agriculture estimates that there are about 200 million acres now in pasture, range, and woodland that could be improved and planted to crops. Given the contamination levels after a 50-city attack as discussed earlier, adjustments of cropping patterns and land use should be sufficient to permit safe recuperation of agricultural output to preattack levels. The conclusion ought to be similar for a 150-city attack.

In the case of the hypothetical area attack discussed earlier, with 20,000 megatons of fission products, contamination of half or more of the area of the United States with dangerous concentrations of strontium-90 would present serious agricultural problems. Even here, countermeasures designed to hold the accumulation of strontium-90 in the general population below the threshold to widespread cancer generation appear to be available. It would also be possible, in an attempt to ensure against agricultural failure, to accumulate a special stockpile of unprocessed foodstuffs sufficient for a year or two at a minimum subsistence level. The government stocks of grain cited above, for example, were valued at about $4 billion.

RECUPERATION AFTER A 50-CITY ATTACK

More vulnerable than agriculture to nuclear attack is a nation's industry. Industrial buildings and equipment are even more concentrated in large cities than population; the 50 largest metropolitan areas contain about a third of the U.S. population but more than half of U.S. manufacturing capital. Thus it is not unreasonable to fear that (even if reorganization problems were surmounted) destruction of the nation's capital might be so severe, and surviving capital might be so out of balance among industries, as to keep industrial production below levels adequate for recuperation.

As part of the over-all non-military defense study, therefore, a rough quantitative analysis of the status of the economy soon after a completely effective 50-city attack, and then a decade later, was undertaken. The basis for the analysis was a table showing the 1952 relationship between national capital (about $830 billion) and the gross national product (about $340 billion). Capital and GNP were connected by way of nine producing sectors, each of which used part of the national capital plus current inputs from other sectors, and produced current inputs *to* other sectors plus finished products that make up the GNP. This table was used to make two main calculations.

First, what could be produced with the surviving capital outside the 50 destroyed metropolitan areas in the first year after reorganization? Here it was assumed that in each sector output would be reduced in the same proportion as its capital—that is, to 30 to 60 per cent of the preattack output, depending on the sector. The finished products available as contributions to postattack GNP, taking account of necessary current inputs to other sectors, could thus be calculated. The results are set forth in Table 3. In the first year after reorganization, it appears that surviving capital would permit a GNP of between 50 and 60 per cent of the preattack GNP, with consumption being a little higher, investment a little lower. On a per capita basis (if as many as 85 per cent of the population should survive), this would be about the same as in 1929 or 1940. Also on a per capita basis, the availability of broad categories of consumption goods—food, housing, and nondurables—seems to be sustainable.

Table 3

POSSIBLE RECUPERATION OF GROSS NATIONAL PRODUCT AFTER 50-CITY ATTACK

(Percentage of preattack)

Categories of National Product	First Year after Reorganization	Eleventh Year after Reorganization	
		Consumption Policy	Investment Policy
Gross national product	56	89	128
Consumption	58	103	137
Food	77	100	124
Housing	60	95	133
Nondurables	51	113	135
Durables (new)	0	86	216
Government	54	72	86
Investment	48	48	150[a]

[a] Sixth year: 202.

The one major bottleneck indicated is in the capacity of the economy to produce new durable goods (metals, building materials, and machinery). The calculation suggests that in order to restore production of new industrial machinery to only a quarter of its preattack level, it would be necessary to stop production of new consumer durables entirely and to reduce production of new military equipment sharply to a maintenance level.

The second calculation examined the possible reconstruction of capital and expansion of GNP over the following decade. Here it was assumed that each sector could expand its output only in the same proportion as its capital was rebuilt. The total rebuilding of capital in the entire economy was limited by the cumulative output of the two sectors, durable goods and construction, which produce new equipment and buildings. Two policy variants were also considered. Under the consumption-oriented policy, investment was held at the postattack level throughout the decade, and as new capital became available it was devoted to producing an immediate increase in consumption. Under the investment-oriented policy, consumption was held constant for 5 years, while the capital-producing sectors were expanded, and then a much larger volume of investment in the last 5 years was directed to a more rapid improvement in consump-

tion. Under either policy the calculation suggests that the status of the economy after a decade of reconstruction could be more favorable than has been feared. A consumption-oriented policy might permit a GNP of about 90 per cent of the preattack GNP, while the more ambitious investment-oriented policy might attain 125 per cent. Thus restoration of the preattack GNP within something like a decade seems a reasonable estimate.

It is apparent that these calculations are rough. There undoubtedly would be narrower bottlenecks within the broad sectors analyzed here. Yet in view of such experiences as the handling of the rubber crisis in World War II, it is hard to believe that they would be disabling; fairly small stockpiles of materials and products needed to overcome narrow bottlenecks are also possible. Serious attention would have to be paid to the possibilities of raising production through more intensive use of capital (for example, by increasing the number of work shifts), of economizing on capital costs of rebuilding plants in the postattack environment (for example, by temporary structures), and of postponing retirement of old plants and equipment during the reconstruction effort. On balance, however, there is probably as much ingenuity and flexibility in the real world as in this analysis.

This general picture of recuperation after a 50-city attack has certain implications for preattack non-military defense policy. Three main kinds of action can be listed in what seems to be a sensible order of priority. First, stockpile construction materials for patching up partially damaged capital during the reorganization phase. Clearly the payoff from such emergency repairs would be great. Research into likely patterns of partial damage in key industries, and into economical ways of patching them up in the postattack environment, is needed. An interesting idea is to stockpile connectors (such as nails, rivets, and welding rods) for use with salvaged materials. Second, preserve normal inventories of metals, building materials, and machinery. Capital in these industries was the major bottleneck revealed in the calculations described here. Research into the amount and kinds of payments needed to persuade private firms to bear the added cost of sheltering their normal inventories is needed. In the

case of machinery, obsolete equipment would be cheap today, but valuable after an attack. Third, shelter complete plants in the durable goods sector of the economy, or possibly standby components of plants. Again, research into the added costs of underground operations in key industries is needed, as further discussed under "Heavier Attacks and Industrial Shelters," below.

HEAVIER ATTACKS AND INDUSTRIAL SHELTERS

Heavier attacks would of course further reduce the industrial capital that might survive for postwar use, and would increase the danger that narrow bottlenecks might limit effective use of that which did survive. A 150-city attack would raise the level of destruction from about 55 per cent of U.S. manufacturing capital to around 70 per cent. And an area attack, which might conceivably collapse all structures in the eleven most important industrial states of the northeast plus all the remaining metropolitan areas in other states, could destroy nearly 85 per cent. Though part of U.S. capital would survive even the hypothetical area attack, it seems clear that some means of preserving a larger fraction would be needed to face postwar recuperation with any real hope.

Blast shelters should be able to provide such protection for industrial capital just as for population. There are differences in the technical problems to be faced—for example, industrial plants that release much heat would require additional cooling equipment, and those with a large volume of material inputs and product outputs would require larger entries and more transport equipment. But there seems little question that either conventionally constructed "medium" shelters or excavated deep rock "heavy" shelters could be designed and built for industrial capital.

Some illustrative examples of the possible costs of such underground construction are also available. The Army Engineers have published engineering estimates of the comparative costs of reproducing three specific plants on the surface and in existing mines. A chemical processing plant was estimated to cost about twice as much underground, a precision manufacturing plant about a third

more, and a warehouse actually 15 per cent less. These costs were for building a nearly identical surface plant underground; further engineering estimates prepared as part of the current study, in which plant designs were adapted to the special characteristics of mine space, indicated that costs could be lower (and perhaps even below those on the surface) for all three types of plant. It should be noted, however, that initial plant construction costs, when placed on an annual basis, are only a small fraction of total annual costs—for example, perhaps a tenth as large as labor costs in manufacturing. This suggests, on the one hand, that a manufacturer might absorb substantially higher construction costs considered by themselves, but on the other hand, that incidental effects of underground plants on location costs and labor costs could be a more serious obstacle. Further research into the economical design of plants in many industries for underground operations, and into methods needed to induce private firms to accept such locations, is indicated.

If the United States embarked on a broad program of underground industrial-plant construction, an important characteristic of the program would be that it could be limited to a fraction of total industrial capital. Some capital could be expected to survive because of its normal geographical dispersal, and if the analysis given in "Recuperation after a 50-city Attack" (page 26) is reasonably reliable, survival of something like half of total capital might permit a respectable recuperation. A crude estimate of the total cost of sheltering about a fifth of manufacturing capital by 1970 was prepared as part of the study, using the published cost differentials cited above, and allowing for different degrees of normal dispersal among some twenty manufacturing industries. Such a program, which might leave the economy somewhat better off after a 150-city attack than with no industrial shelters after a 50-city attack, was calculated to cost on the order of $30 billion, though the figure is surrounded with great uncertainty.

MINES

Mines for the excavation of low-valued ores such as limestone seem to have many possible uses in non-military defense. We have

already referred to adapting them for temporary population shelters, for warehouses (at costs competitive with surface warehouses), and for manufacturing plants. Combinations of these uses can be planned —for example, permanent underground industrial plants usable as temporary population shelters. Explicitly military functions are also possible—for example, control and communications centers in the air-defense network. Accordingly, a quick survey of the availability of such mines was undertaken as part of the study.

A reasonable estimate is that the United States now has at least 750 million square feet of usable space in mines with suitable characteristics for industrial or population shelters. This is 10 to 15 per cent of existing manufacturing floorspace; alternatively, at 20 square feet per person it could accommodate nearly a fourth of the U.S. population. Of course, part of this space is not conveniently located for use as industrial shelters, and the bulk of it would be usable as population shelters only if outfitted and in the event of strategic evacuation. But it seems reasonably clear that mine space is a major national asset, the possible uses of which have not been adequately explored.

In the longer run it ought to be possible to expand markedly the availability of such mine space at convenient locations. The bulk of low-valued ores currently being produced comes from quarries. But firms with mining operations sometimes compete in the same markets, and the choice between quarrying and tunneling is based on cost for the particular deposit being exploited. Payment of a premium for low-valued ores excavated from mines rather than from quarries could over time stimulate considerable conversion of operations. Limestone, for example, is currently sold at prices in the neighborhood of a dollar per ton at the minehead, which is equivalent to about a dollar per square foot of floorspace created. Thus a premium of as little as 50 cents per square foot could have a widespread effect on operations in the limestone industry. Premiums could also affect the location of mining operations, since there seem to be billions of square feet of readily excavatable rock formations (though at higher costs) suitably near or under many large U.S. cities.

V. Some Possible Non-Military Defense Programs

Our discussion of population shelters, long-term fallout, and economic recuperation suggests (despite the many uncertainties involved) that non-military defense measures could significantly alleviate the catastrophe of a nuclear war. There appear to be technically promising possibilities for protecting many people from immediate blast and fallout, for enabling the population as a whole to carry on despite long-term radiation, and for restoring a reasonable standard of living within less than a generation. It is important to consider the costs of these technical possibilities, however, since today there are many strong claimants on the government budget, and thus on the incomes of voters and taxpayers. It is especially important to consider a range of costs for alternative programs that attempt different levels of performance. Only rough cost estimates are possible with the imperfect information now available, but as part of the over-all study an attempt was made to indicate their order of magnitude for several coherent programs.

EXISTING PROGRAMS AND ASSETS

In the last few years the U.S. government has been spending between $50 million and $100 million a year on non-military defense, apart from stockpiling. This figure is extremely small both in relation to the entire national defense budget and in comparison with the costs of certain possible non-military defense measures discussed above. However, a good deal could probably be done with expenditures as small as two to three times recent annual budgets, particularly by taking advantage of existing assets.

A non-military defense program costing $200 million to $300 million could probably accomplish most by concentrating on a system of improvised fallout shelters outside the large cities. Such a program might include the following major elements: identifica-

tion of existing buildings in small cities and towns that provide high attenuation factors against fallout; provision of sandbags, water tanks, and other minimal supplies needed to convert these buildings into operating fallout shelters for short-term occupancy; widespread distribution of radiation meters, as discussed earlier; preparations to take advantage of partial strategic evacuation, in case international tension should make it desirable; planning and practice of tactical evacuation of cities for which fallout accommodations are available in a belt 20 to 50 miles away from the center. None of these actions would be very expensive, and the resulting system might cover only part of the population, yet in appropriate circumstances they might save millions of lives. Once the government embarked on such a program, helpful private actions would be more likely.

Existing government assets could also be adapted in certain respects to non-military defense objectives. The Office of Defense Mobilization now has a strategic stockpile containing over $6 billion worth of industrial raw materials, accumulated to support a war mobilization of several years. Modification of the stockpile with an eye to economic recuperation after a short nuclear war would be sensible. Further processing of part of the raw materials, so that they could be more quickly used amid the widespread destruction following a nuclear attack, might possibly be financed by gradual disposal of unprocessed materials. The government also owns $2 billion to $4 billion worth of war-reserve machine tools. These are largely stored at plants producing military equipment, to facilitate rapid expansion of output during a mobilization. Here a reasonable adaptation would probably be to store the tools either in shelters or in non-target locations so that they could be expected to survive a nuclear attack. Certainly such tools should not be disposed of, as has been considered, without evaluating their non-military defense contribution. The Army, Navy, and Air Force have several billions of dollars' worth of obsolete military stocks, ranging from generally useful items like clothing to specialized items like jet engines. These might be investigated to see how much could be useful for non-military defense as well as for military reserves. Finally, the Commodity Credit Corporation has $7 billion to $8 billion worth of agricultural

products, accumulated in connection with the price-support program. Fortunately, most of these holdings are already geographically dispersed, but some further improvements are perhaps possible.

TWO SCALES OF SHELTER PROGRAMS

The essential ingredient of non-military defense programs that offer greater hope of alleviating nuclear disaster is a comprehensive and coordinated system of population shelters. There appears to be a wide range in the cost of such programs, however, depending on the degree of protection attempted for residents of large cities and the amount of associated preparation for postattack survival and recuperation. To illustrate the range of costs, two hypothetical programs are presented in Table 4. These programs are comparable to the two systems whose performance was calculated in the section on "Performance of Possible Shelter Systems under Hypothetical Attacks" (page 10).

Table 4

ESTIMATED INITIAL COSTS OF TWO POSSIBLE NON-MILITARY DEFENSE PROGRAMS

(Billions of dollars)

	Program A— System of Fallout Shelters plus Limited Economic Support	*Program B*— System of Blast and Fallout Shelters plus Extensive Economic Support
Population shelters		
"Heavy" blast shelters (500 psi and up, $700 per shelter space)	0	28
"Medium" blast shelters (50 to 200 psi, $400 per shelter space)	0	20
"Light" fallout shelters (improvable later, $150 per shelter space)	15	26
"Improvised" fallout shelters ($10 per shelter space?)	1	0
Food rations and stockpile (40 cents per ration per day)	1.5	25
Nonfood stockpile	1.5	20
Industrial shelters	1	30
TOTAL	20	149

Program A is designed to provide fallout protection only (requiring several hours of warning to save many people in the large cities), plus economic support appropriate for a 50-city attack. It includes no heavy or medium shelters, but light and improvised shelters (an equal number of each) are distributed to accommodate the entire population after strategic or tactical evacuation. It provides 30 days' special rations for about two-thirds of the shelter-places, and presumes that people carry additional food into the shelters with them. The small nonfood stockpile concentrates on decontamination equipment and construction materials for patching up damaged capital equipment. The industrial shelters represent largely the cost of inducing firms in durable-goods industries to shelter their normal inventories.

Program B is designed to provide both blast and fallout protection with 30 to 60 minutes of warning, plus economic support appropriate for a 150-city or larger attack. It includes heavy and medium shelters for all residents of the 150 largest cities, as well as light shelters for the rest of the population, with extra spaces for evacuees from the large cities in case that proved feasible. It provides 90 days' special rations for each place in a shelter, plus $15 billion for a bulk food stockpile. The substantial nonfood stockpile to facilitate economic recuperation includes much more decontamination equipment and construction materials, as well as selected parts for key industries, and the cost of increasing available mine space. Finally, Program B provides industrial shelters for something like a fifth of preattack manufacturing capital.

Quite rough estimates of the costs of these two programs, as set forth in Table 4, suggest that non-military defense programs may range in cost from $20 billion to $150 billion (that is, $2 billion to $15 billion a year over a decade), depending on the scale attempted. These costs have been estimated without allowing for a tendency in many public construction projects to provide more luxurious accommodations, but on the other hand they represent programs that are coherent and complete. Intermediate programs at intermediate costs are also possible.

The desirability of adopting a non-military defense program at any

particular scale of cost can only be evaluated, of course, in a broader context. One element in the problem is the willingness of U.S. voters to support appropriations for all national-defense purposes combined. Another element is the estimated performance and cost of other kinds of national-defense expenditures: long-range retaliatory forces, facilities for active defense of the United States, and capabilities for conducting limited wars overseas. No attempt has been made in this study to carry through such an over-all examination of the national-defense problem. Costs of various possible non-military defense measures should be considered in such an over-all evaluation, however, and the rough estimates presented here may serve to guide more thorough investigations.

TIMING AND PHASING PROBLEMS

Any large new government construction program normally takes years to put into effect, and a non-military defense program near the more ambitious end of the cost scale might take especially long to implement because of the many new problems to be faced. Yet it is important, before carrying out any construction, to clarify the uncertainties that at present surround non-military defense measures—both to provide a firmer basis for a policy decision as to the appropriate scale of effort, and to improve the performance or lower the cost of any measures that are chosen. Considerable thought has therefore been given to possible ways of clarifying these uncertainties without losing much time in the normal construction process.

The most promising approach appears to consist in prompt initiation of a broad research, development, and planning effort in the non-military defense field. The design and planning of specific measures should be carried sufficiently far so that if it is later decided to undertake them, normal lead times could be significantly cut. Prompt investigation and decision would also permit measures that work gradually over time to be useful, such as premiums for the creation of suitably located mine space.

Another approach, if a large-scale non-military defense program should be decided on, would be to create a temporary stockpile of

materials needed in the construction of shelters. Such a "starter set," accumulated while legal and other arrangements were being made in localities throughout the country, would even out the impact of the program on the economy. More important, it might permit a program that was originally planned to take perhaps a decade to be markedly accelerated if international relations became unexpectedly tense. A crash program, akin to the expansion of military production in the Korean war, might be able to proceed without critical material shortages. There are also possibilities for combining such a "starter set" with the stockpiling of materials for postattack recuperation.

Phasing a non-military defense program also raises difficult choices. On the one hand, early capabilities are desirable. On the other hand, the enemy threat can be expected to continue to mount, both in terms of weapons characteristics and in terms of effective delivery systems; it is important that any measures adopted now continue to be useful in the late sixties. Fortunately the relatively inexpensive measures discussed under "Existing Programs and Assets" (page 33) could provide some early capabilities, without costly obsolescence later. Radiation meters in particular would continue to be useful in any program. Moreover, with forethought, elements of the more ambitious programs examined in the section entitled "Two Scales of Shelter Programs" (page 35) could provide early protection and still be improvable in the future. For example, light fallout shelters could be designed for conversion to medium blast-and-fallout shelters through the addition of better blast doors. Also, the first shelters built ought to have sufficient utilities to accept severe overcrowding; only as more shelters were built could the habitability standards set as an objective be approached.

VI. Interactions with Other Aspects of National Defense

ACTIVE OFFENSE

The U.S. Strategic Air Command defends the population and economy principally by deterring general war through the threat of retaliation. Beyond this, if deterrence failed, SAC would continue to play a central role in the defense of U.S. cities. It could (*a*) force the diversion of limited Soviet long-range forces to attacks on SAC rather than on cities, (*b*) limit total damage by making counterforce attacks on the Soviet strategic force and ending the war, and (*c*) by a combination of these, gain time for the population to take advantage of non-military defenses. It should be stressed that protection for SAC is as important for its role in limiting destruction of cities as for its deterrent posture. It would be sensible to locate SAC bases and missile centers well away from large cities, in sparsely populated areas in the interior of the country. In addition, a program of sheltering planes, missiles, weapons, and essential support facilities would make an enemy's problems much more difficult. The importance for the civilian population of limiting the number of cities attacked on the first strike, and of obtaining warning of impending strikes, has already been indicated in the casualty calculations discussed in the section on "Performance of Possible Shelter Systems under Hypothetical Attacks" (page 10).

ACTIVE DEFENSE

Active defense and non-military defense mutually support each other. The mere existence of active-defense forces helps to limit civilian casualties by compelling the enemy to launch larger raids, which are more likely to be detected and thus to provide warning. Moreover, active defense may cause further diversion of weapons from city targets to air-defense targets and to the task of penetrating

to SAC targets. Finally, active defense of the cities themselves, even though only partially effective, can limit total national casualties by compelling the attacker to limit the number of cities attacked, by reducing the number of bombs on target through attrition, by degrading the accuracy of the attack, and by forcing the attacker to design countermeasures that are expensive and that reduce bomb loads. It is especially important to prevent an enemy from having a free ride in follow-up attacks, because without continuing resistance he could cause almost any level of casualties he wished.

On the other hand, non-military defense measures contribute most importantly to active defense by making attainable levels of performance worth while. An effective non-military defense system could sharply reduce the number of casualties per enemy bomb, and thus give an active-defense system capable of screening out a substantial fraction of the enemy weapons, even if not all of them, a more important role in the national defense. Non-military defense also helps active defense in more technical ways—such as by making the enemy attempt more accurate (and more easily disturbed) delivery systems, and by permitting the defensive use of larger atomic warheads at closer range.

SOVIET NON-MILITARY DEFENSE

Non-military defense should also be examined through the looking glass: What would be the implications for U.S. policy if the Soviet Union embarked on a major non-military defense program? It is not widely realized that Russia already has a respectable program, including reinforced basement shelters and a program of mass civil-defense education. It is true that the specifics of the Soviet program seem more appropriate to small-yield fission weapons than to large-yield thermonuclear weapons. But even the present program, given the warning inherent in making the first strike, would almost surely be able to reduce casualties significantly. Further, it could readily serve as the base for a more comprehensive program.

The Soviet Union would have several advantages over the United States in implementing a major shelter-construction program. The

real cost of constructing heavy and medium shelters for Russian cities would be only about half that of constructing similar shelters in the United States, because the Soviet urban population is smaller and less concentrated. Fallout shelters could be readily improvised for the rural population, because most existing structures are built with thick earth and timber walls and with small windows and doors. On the other hand, extensive protection of industrial capital for postattack recuperation and accumulation of large food stockpiles would probably be more difficult.

If the Soviet Union were to embark on a large-scale non-military defense program, it could have important implications for U.S. defense policy. Non-military defense might strengthen the resolve of Soviet leaders and make it more difficult to deter them either from major provocation elsewhere in the world or from direct attack on the United States. In particular, it could make a Russian first strike appear more attractive. And if deterrence failed, hardening Soviet targets could make it more difficult for U.S. offensive forces to accomplish heavy retaliation.

VII. Conclusion: Some Policy Suggestions

A BROAD RESEARCH, DEVELOPMENT, AND PLANNING PROGRAM

The major conclusion of this study of non-military defense is that there are more promising possibilities for alleviating the disaster of a nuclear war than have been generally recognized. There appear to be possibilities of providing inexpensive fallout protection for people outside blast areas, of constructing blast shelters capable of standing up to thousands of psi, of carrying out strategic or tactical evacuation if sufficient warning is available, of limiting the long-term biological damage to the population resulting from total radiation, of adopting countermeasures to contain the strontium-90 problem even after very large attacks, of ensuring a minimum supply of food immediately after the attack, of reconstructing destroyed industrial capital within much less than a generation, and of integrating non-military defense measures with other aspects of national defense. Moreover, some hypothetical non-military defense systems that have been examined seem to be capable of saving tens of millions of lives in the face of conceivable enemy attacks, and of preserving a foundation for meeting long-run radiation hazards and for post-attack economic recuperation.

On the other hand, each of these possibilities is at present surrounded by considerable uncertainty, with respect to both performance and cost. There is a wide range in the probable costs of alternative non-military defense systems, and such systems must be evaluated in conjunction with other elements in the U.S. national defense posture. Further investigation is indicated, to pin down the uncertainties, to make sure that serious difficulties haven't been overlooked, and to provide a sounder basis for evaluation.

Accordingly, the principal policy suggestion stemming from this study is that the United States ought to undertake a serious research, development, and planning program in the field of non-military de-

fense. Such a program should be broad in that it addresses itself simultaneously to the whole complex of issues involved in non-military defense, as touched on in this study. Such a program should also be detailed and concrete, so that if a comprehensive non-military defense system is later decided on, it could be initiated quickly.

It should be stressed that it does not appear sensible to embark on a comprehensive non-military defense program now without such prior research. An ill-considered program could be costly, threatened with obsolescence, and inconsistent with other important elements of national defense.

An appropriate scope for such a research, development, and planning program can be illustrated with a $200-million budget, spread over 2 or 3 years. In this connection, we may note that it costs $100 million to $200 million to develop an interceptor aircraft, $500 million to $1 billion to develop an intercontinental bomber, and $1 billion to $2 billion to develop an ICBM. Moreover, if non-military defense measures involving billions of dollars should ultimately be adopted, such prior research could readily pay for itself by saving only a small percentage of the total cost.

A sensible allocation of funds to individual projects within a $200-million budget has also been prepared. This program is discussed in another document to be issued separately,* but a brief summary (with selected examples from the detailed program) is set forth in Table 5. The goal was to make sure that every important subject was adequately covered, rather than to see that every dollar was spent economically. The detailed program should indicate, however, that the issues raised by non-military defense are concretely researchable.

REORIENTATION OF PRESENT PROGRAMS AND EXISTING ASSETS

Apparently there are a number of instances in which substantial non-military defense capabilities seem to be attainable at modest cost, by reorienting present programs and the management of exist-

*Herman Kahn *et al.*, *Some Specific Suggestions for Getting Early Non-Military Defense Capabilities and Initiating Long-range Programs*, The RAND Corporation, Research Memorandum RM-2206-RC, July 1, 1958.

Table 5

A PROGRAM OF RESEARCH, DEVELOPMENT, AND PLANNING IN NON-MILITARY DEFENSE

(Millions of dollars)

PERSONNEL SHELTERS		$ 65
Example: 5.	Detailed studies of shelters designed for ten representative medium and small cities. The studies should proceed from engineering proposals through feasibility checks to final designs. Various levels of adequacy, phasing questions, and possibilities of future improvement should be considered. ($6)	
MINES		15
Example: 6.	Preliminary design of underground plants in twenty important industries. Emphasis should be on modifying surface designs to exploit mine characteristics. The study should include all factors that influence the profitability of operations, not just construction costs. ($3)	
CONVENTIONAL INDUSTRIAL SHELTERS		5
Example: 1.	Study of the practicability of protecting essential parts of plants in twenty important industries, using conventional protective construction. ($1)	
PRIVATE INDUSTRY STUDIES		15
Example: 1.	Analysis of inventory protection in twenty important industries. Emphasis should be on fixed capital, working capital, and operating costs of alternative measures—transferring inventories to nontarget locations, to constructed shelters near plant, to mine shelters in available locations. If possible, studies should be contracted with leading firms. ($2)	
SPECIAL EQUIPMENT AND PROCESSES		15
Examples:	Engineering design studies of excavating machines, blast doors, ventilation equipment, shelter utilities, intershelter communication, construction with salvaged materials, radiation shielding for vehicles.	
ANTICONTAMINATION AND FALLOUT		30
Example: 4.	Study of fallout countermeasures—including decontamination equipment, wash-down systems, shielding methods, decontamination of food and water, changes in farming techniques. ($13)	
MEDICAL ASPECTS OF SHELTERS		10
Example: 7.	Research in acute radiation therapy, including medicines to ameliorate the effects of temporary exposure, protective clothing, and methods of medical treatment. ($2)	

[continued on p. 46]

Table 5—continued

FOOD AND AGRICULTURE	15
Example: 4. Controlled experimentation with various diets, aimed at developing lowest-cost shelter rations and evaluating post-war survival diets. ($3)	
EXPANSION OF GOVERNMENT STUDIES	10
Example: 1. Investigation of non-military defense adaptations of existing government activities—joint-use construction of schools, government buildings, highways; city planning; foreign-aid programs. ($1)	
ACADEMIC STUDIES	5
Examples: Theory of the response of buried shapes to blast pressures, inducements to private firms to preserve obsolete machinery, social and psychological influences on shelter morale. Emphasis should be on one-man projects that tap intellectual resources widely.	
SYSTEMS ANALYSIS	10
Analysis of performance and cost of non-military defense systems in a wide variety of war situations, and of interactions between non-military and military defense, is essential for evaluation of measures studied in other parts of the program.	
MISCELLANEOUS	5
TOTAL	$200

ing assets. Accordingly, a second general-policy suggestion is that wherever such fairly inexpensive possibilities exist, they should be introduced, up to an additional cost of perhaps $300 million. Such an inexpensive program might save millions of lives, facilitate economic recuperation, and phase into extensive shelter construction if that should later be decided on. Three specific kinds of reorientation can be suggested.

First, planning in government civilian agencies should be primarily oriented to a short thermonuclear war. The objective should be to protect civilians, aid their survival, and rebuild the economy, rather than to mobilize war production to support a large overseas army. A clarifying directive from the National Security Council would help to place mobilization planning, and the expenditures currently being made in this field, on a more plausible basis. Correspondingly, plan-

ning in the military departments might place greater emphasis on the interaction of military operations with non-military measures to protect civilian society.

Second, the management of existing stockpiles should be reoriented insofar as practicable to support non-military defense. The government now owns about $20 billion worth of industrial raw materials, machine tools, obsolete military stocks, and surplus agricultural commodities. Inexpensive actions to process, store, relocate, or protect these stockpiles might be initiated, as discussed under "Existing Programs and Assets" (page 33). Certainly the government should not dispose of these stocks without first considering seriously their possible contribution to non-military defense.

Third, current non-military defense programs should be reoriented to emphasize improvised fallout protection, procurement and distribution of radiation meters, and arrangements for strategic and tactical evacuation of large cities. A realistic program of this sort on a reasonable budget (see "Existing Programs and Assets," page 33) could provide a sensible objective for existing agencies in the non-military defense field, and thus make their efforts more productive.

PROMPT CONSIDERATION OF LONG-TERM MEASURES

Certain measures that might be incorporated in a comprehensive non-military defense program would come to fruition only over a period of years. Such measures, therefore, ought to be considered and (if sound) brought into operation as soon as possible. Four specific long-term suggestions of this nature were developed in the study.

The first suggestion is a program to stimulate the creation of suitably located mine space. As discussed on pages 30 and 31, mine space seems to have many non-military defense uses, and it should be possible to obtain such space much more cheaply by small premiums to mine operators over a period of years than in a crash program of mass excavation.

Second, an interesting idea that might contribute to the solution of

institutional problems during postattack reorganization, and that might permit some of the costs of preattack measures for economic recuperation to be prefinanced outside the federal budget, is a War Damage Equalization Corporation. Such a corporation might sell "insurance" on a compulsory or voluntary basis to financial institutions, business firms, and individual property owners. These funds might then be invested in the accumulation of nonfood stockpiles, in the creation of industrial shelters, and in other measures that would increase the real assets available after a war. The "insurance" claims on the corporation could serve as a basis for restoring postattack operations of financial institutions and business firms, and for redistributing property losses more equitably among firms and individuals. Other arrangements to carry out these functions are of course also possible, and the entire subject deserves serious consideration.

Third, given clear and realistic orientation as to the nature of non-military defense problems, private professional organizations ought to be able to make important contributions to their solution. To cite a single example, if the government provided such guidance, the American Society of Civil Engineers might be quite helpful in developing structural designs for fallout shelters in small cities with peacetime as well as wartime uses.

The fourth suggestion has to do with initiation of long-term planning for governmental civilian agencies in the non-military defense field. The objective should be to establish independent staffs whose full-time purpose is to keep abreast of prospective military and technical developments and to plan corresponding adaptations of current agency operations. Long-range planning is now accepted in the military departments, and it is equally important for non-military defense.